Will humans adapt to the movement of humanoid robots?

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***Abstract*— Adaptation to humans is indeed very important for humanoid robots and recent research is focusing heavily on this issue**[1]–[3]**. However it is also necessary, especially in social contexts of HRI, to understand the mechanisms that would trigger adaptation of a person to a robot. The aim of this and future related studies is to replicate the paradigms of human-human interaction with iCub, and learn how to activate and enhance this adaptation in humans interacting with humanoid robots. Here we present results from an experiment involving both a person and iCub in a collaborative joint task** [4]**, then we discuss subjects' adaptation to the robot and how to enhance it in future versions of the experiment.**

I. Introduction

Building humanoid robots capable of interacting smoothly with a human partner is one of the main goals of HRI. Recent studies focused more on the side of making robots adjust to the person in collaborative tasks [1]–[3], but cooperation between two humans often implies reciprocal adaptation[5]. For this reason it might be important to understand how to lead the person to harmonize with the robot rhythm, while performing a joint action. Here we present and discuss results of an experiment, designed to investigate whether subjects are prone to adjust their behavior to the robot during a collaborative joint task [4]. In this experiment a person had to cooperate with iCub to fill a box with Lego blocks. To evaluate whether subjects were eager or not to synchronize with the robot, we set two different speeds for its movement. After the trials, we asked subjects personal opinions on some aspects of the interaction.

II. Methods

The experimental setup was the following: the subject was sitting in front of the robot with a big box on a table between them. An experimenter put one Lego block in the open hand of the subject and one on the open hand of the robot at the same time, then the two had to put the block in the box. The next block was passed only when both had finished their action in order to always have a common starting time (Fig. 1). Subject's task was to load a box with Lego blocks, together with the robot. Subjects performed 2 sessions, each consisting of 10 repetitions. The two sessions are differentiated by the speed of the robot (See Fig.1; Slow: 0.084 m/s ; Fast: 0.151 m/s). We set the "Fast" speed to have the robot performing the task in a reasonable time. Then we chose a "Slow" speed forcing the subjects to put a consistent effort if they wanted to synchronize with iCub. After the experiment we asked subjects to fill a short questionnaire to gather information such as experience with

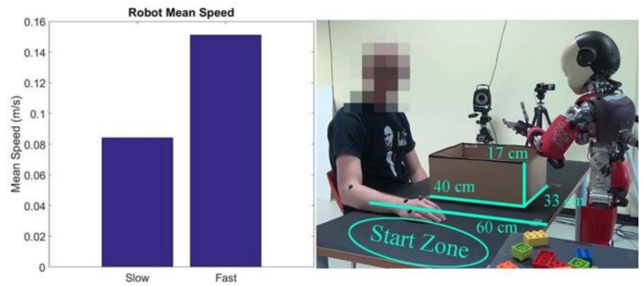

Figure 1. Mean speeds of the robot in the two conditions and experiment setup

robots, which part of the robot they paid more attention to, and if they felt influenced by the behavior of iCub, then we gave the possibility to add open comments about the interaction with the robot. The experiment was performed by 15 participants (Mean age 30 years± 5 SD, 6 males, 9 females, 1 Left handed). We exploited motion capture data to calculate the duration of the transport action, from the start to the drop point, for the subjects and the robot. We acquired videos of each session and kinematic data of both the subject and the robot with a motion capture system. We programmed the robot with the existing Cartesian Interface [6], in order to have a movement compliant with the Two-Thirds Power Law of human motion [7]. To keep a simple behavior, we made iCub follow its hand with its gaze.

III. Results

To estimate adaptation of the subjects we introduced two parameters: a) difference between transport duration of the person and transport duration of the robot, and b) how the transport duration of the person changed according to the duration variation of the robot in the two conditions. The first parameter (Duration Difference) gives a measure of how similar to the duration of the robot is the mean duration of the subject. The second parameter (Slope Difference) returns a measure of how much the subject adjusted his/her duration, according to the variation of iCub's speed (Fig. 2, see [4] for more details). For both parameters lower values mean more adaptation. From the chart in Fig. 2 appears a progressive degree of adaptation. To deepen the analysis of this result, we combined it with data acquired from the questionnaires. Approximately 90% of the subjects responded that they felt influenced by the robot, but as we can see from Fig. 3 panel A, 50-75% of them did not show a strong adaptation. In panel B of Fig. 3 we can see that all the subject who declared to have low or no previous experience with robots, are in the group with the lowest degree of adaptation. Lastly, in the question "*To which parts of the*

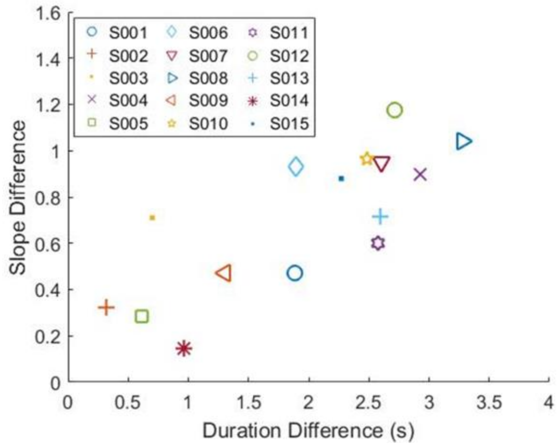

Figure 2. Degree of Adaptation. Duration difference indicates the gap between the transport duration of the subject and the transport duration of the robot. Slope difference shows how the duration of the subject changed in relation to the variation of transport duration of the robot. See text and Methods for details.

robot did you pay more attention to?", 90% of the subjects answered *"eyes"* and *"arm"* while the other 10% wrote different things such as *"face"* or *"torso"*.

IV. Conclusion

When collaborating to achieve a common goal, humans try to find a good tradeoff between their best performance and the best of the counterpart, continuously adapting one to the other [5]. In this study we wanted to understand whether these mechanisms could be triggered also while interacting with a humanoid robot [4]. We designed a simple joint task and measured if subjects' behavior was affected by the robot. Results show that even if almost all the subjects felt that they were influenced by iCub, only about 40% had a significant adaptation. To investigate possible reasons why only a small subset of the participants adapted significantly, while 90% of them had the impression to be influenced by iCub, we analyzed some individual characteristics like experience with robots or focus of attention. From questionnaires answers, we noticed that subjects with a higher experience with the robot tend to adapt better to its pace. This could be due to their knowledge of the limits of the robotic platform. Furthermore we believe that the slow speed of the iCub, together with the lack of mutual gaze, could have provided a less natural interaction to the subjects. In fact, most of the participants answered that, during the experiment, they paid more attention to the eyes of the robot and many of them declared in the free comments that, in their opinion, the interaction would have been more pleasant if the robot had looked them in the eyes. Some participants claimed also that they expected the robot to change its behavior according to their motion, but they could not notice any kind of adaptation from iCub. We believe that these are the two main factors that could improve the feeling of mutual cooperation in the task of our experiment.

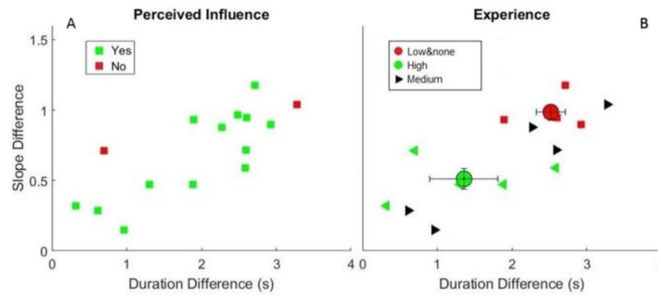

Figure 3. Subject's perceived influence by iCub (A) and effect of previous experience with robots (B) as a function of actual adaptation. Bigger circles correspond to group averages for a subset of groups (see Results section). Error bars represent standard error of the mean.

V. Future Work

In our future work, we plan to implement mutual gaze and reciprocal adaptation in the behavior of the robot, expecting that these features would enhance drastically the feeling of a pleasant cooperation with iCub, raising consequentially the level of adaptation also on the human side. We will also analyze more in depth the data of the motion capture system, paying special attention to the speed of human movements, looking for possible correlation with the duration described in this paper. Ultimately we want to perform the experiment implementing in the robot a new type of movement that does not comply with the Two-Thirds Power Law, to investigate how this can affect human perceptions.

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